

FWP #: 61253

FWP Title: A High Density Microelectronic-Tissue Hybrid Sensor for Imaging

B&R Code: KP140103

Principal Investigator: Auciello, Orlando

Work Proposal Description:

The overall goal of this proposal is to develop a high-density microelectronic-tissue hybrid sensor or intra-ocular retinal prosthesis. The contribution of ANL to the project includes two main tasks:

(a) Implementation of the ANL patented ultrananocrystalline diamond (UNCD) film technology to produce a biologically compatible, chemically resistant, hermetically protective coating to cover the implanted microchip. This coating is grown using a microwave plasma chemical vapor-deposition (CVD) method featuring a CH_4/Ar plasma chemistry that results in the production of insulating UNCD coatings. A new approach to be explored in FY06 will be to include SiC or biocompatible oxide coating underneath the UNCD layer to improve hermeticity.

(b) Investigate biocompatible oxides such as Al_2O_3 and TiAlO deposited by atomic layer deposition, as hermetic coating for encapsulation of the Si microchip, or as underlayer to the UNCD coating.

(c) Development of high-dielectric constant capacitors for integration with the retina microchip as input/output RF signal coupling capacitors. This work is new and will involve research on deposition of high-K dielectric layers on Si substrates, via sputter-deposition and atomic layer deposition and integration with the microchip that is the main component of the artificial retina.

b. Publications: 3

c. Purpose:

- Optimize the properties of UNCD hermetic coatings as biologically compatible, chemically resistant, bioinert coating for encapsulation of the implantable Si microchip in the human eye. This work will include exploring insertion of SiC or oxide layers underneath the UNCD coating to increase hermeticity via heterostructured coating
- Develop high dielectric constant biocompatible capacitors for integration with the microchip as input/output RF signal coupling capacitors.
- Investigate biocompatible oxide coatings as hermetic encapsulating coatings or underlayers to UNCD layers.

e. Approach:

For the work on hermetic UNCD and oxide encapsulating coatings the personnel will be: O. Auciello (10%), J.A. Carlisle (10%), B. Shi (postdoc) (100%).

For the work on the high-K dielectric capacitors, the research will focus on developing high-K dielectric films and integration with the microchip. The personnel will be O. Auciello (5%) Il-Seok Kim (postdoc) (100%).

f. Technical Progress:

- We demonstrated that hydrogen incorporation into UNCD films resulted in increased insulation characteristics of the films and lower leakage currents (down to $\sim 10^{-7}$ A/cm²) in electrochemical tests in saline solutions. This effect resulted from hydrogen incorporation into the grain boundaries that satisfied dangling bonds, thus reduced conduction electrical conduction paths through grain boundaries.
- We conducted the first in vivo test of UNCD in rabbit eyes for six-months, which showed a good performance for one sample and a partial failed on the second sample. We are currently conducting a second six-month in vivo test of UNCD coated Si chips, and after about three months of implantation the UNCD coatings are performing much better according to reports from Doheny researchers.
- We designed jointly with the manufacturer the atomic layer deposition system to be used in the new oxide film work. The system has been ordered and is scheduled to be delivered by the first part of April 2006.

g. Future Accomplishments:

- We will explore new approaches to hermetic Si micropohip encapsulating coatings to improve the hermeticity via insertion of underlayers such as biocompatible SiC or oxide, and /or overlayers such as parylene.
- We will perform research on alternative biocompatible oxide layer as microchip encapsulating coatings isolated or in combination with UNCD and/or parylene.
- We will perform research to develop biocompatible high-K dielectric input/output coupling capacitors for integration into the retina microchip to miniaturize the overall retina implant.

h. Relationships to Other Projects:

We will interact with the following groups that are part of the artificial retina project in an effort to optimize the overall chance for success of the overall project:

- Work with the group of the University of California (Santa Cruz), which is designing the Si microchip, to achieve integration of the proposed coupling input/output capacitors
- Work with Second Sight to develop the hermetic coating needed for eye implantation of the Si microchip
- Work with Doheny Eye Institute researchers for continuing critical in vivo tests of the encapsulating coatings
- Work with Sandia Lab researchers to explore integration of parylene coating into heterostructured Si microchip encapsulating coatings

i. NEPA Requirements Required: NEPA review and assessment has been completed in accordance with DOE NEPA Compliance Order 451.1B

j. Explanation of Milestones: NA

k. Deliverables:

- UNCD Coated high conductivity Si samples and real swizzles, with and without under and over layers, to Second Sight for chronic and soaking tests
- Oxide coated high conductivity Si and real swizzles to Second Sight for chronic and soaking tests.
- Coupling capacitors to the UCSC group for testing of electrical properties of the coupling capacitors

l. Performance Measures and Expectations:

- Development of hermetic encapsulating coating either as single or multilayered coating based on UNCD alone, or UNCD with under- and /or over-layers
- Demonstration of high-K dielectric coatings capable of yielding capacitors with properties compatible with input/output microchip coupling capacitors

m. ES&H Considerations: Normal ES&H considerations associated with laboratory work as outlined in Argonne's ES&H manuals will apply

n. Human or Animal Subjects Activities: N/A

o. Security Requirements: N/A